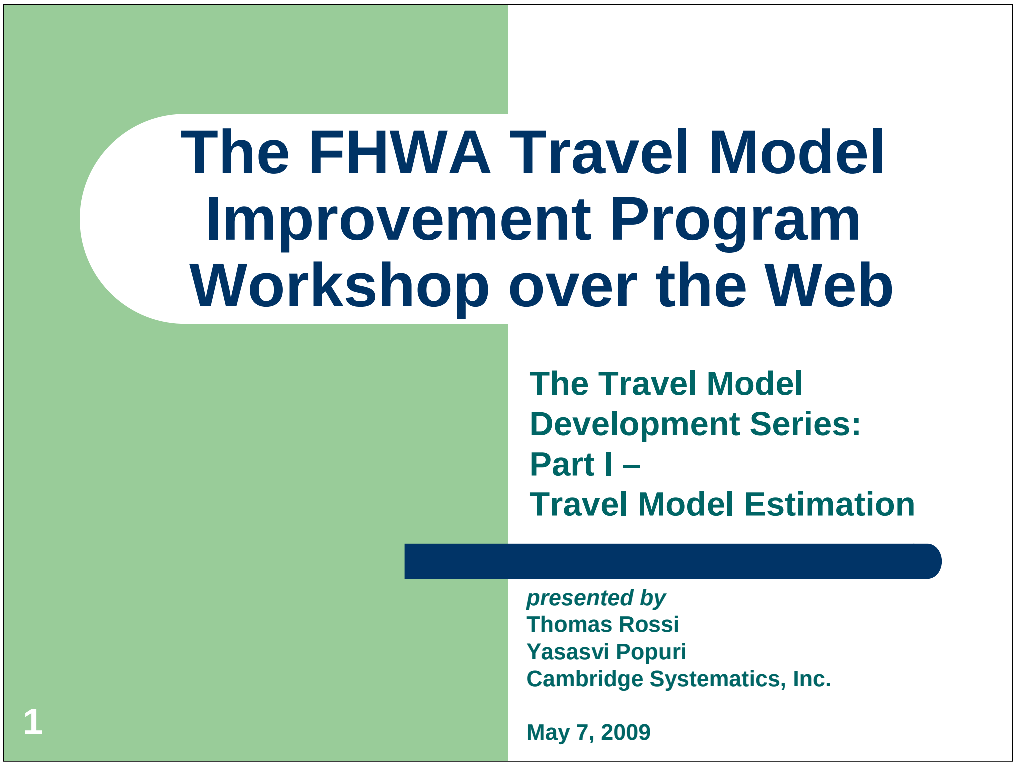


**Key Message: Purpose of the Webinar Series**

**Details:**

Welcome to the FHWA TMIP Workshop over the Web.  This workshop is targeted at Transportation modelers who have a low to moderate level of familiarity with the estimation and validation of travel models.

This series of webinars will introduce the development of model estimation data sets, the structures of the various model components, and the procedures for estimating models. The workshop will include lectures, discussion, and “homework,” that participants will be expected to complete between sessions.

## Webinar Outline

- Session 1: Introduction – October 16, 2008
- Session 2: Data Set Preparation – November 6, 2008
- Session 3: Estimation of Non-Logit Models – December 11, 2008
- Session 4: Estimation of Logit Models – February 10, 2009

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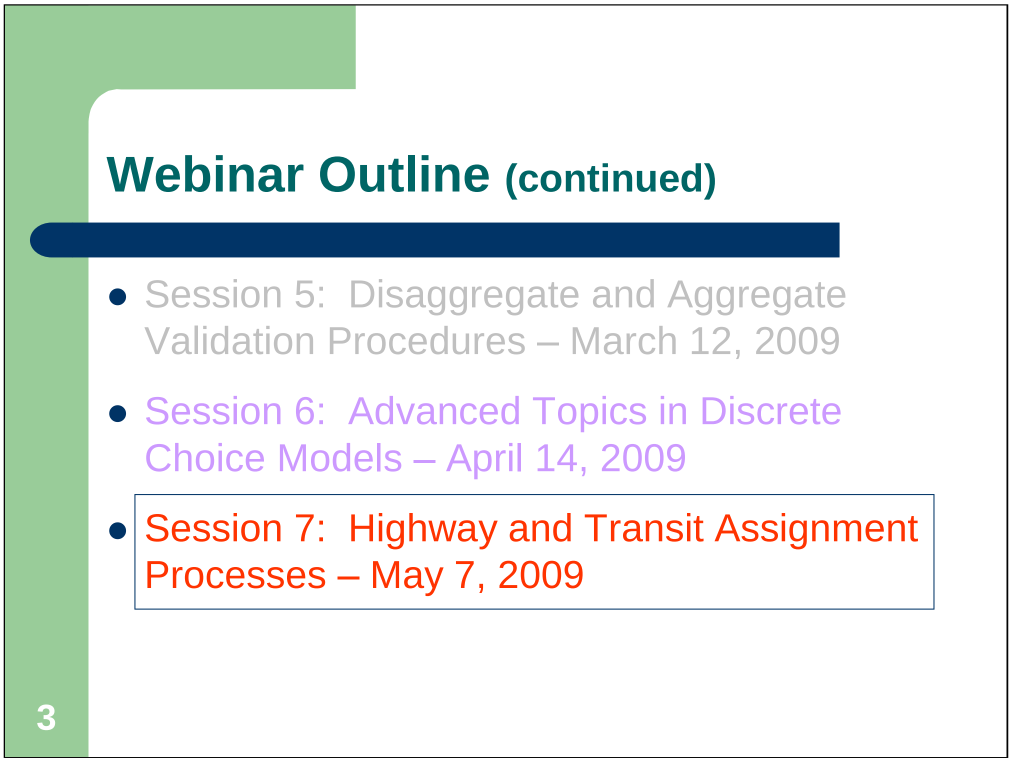
**Key Message: Past Sessions**

**Details:**

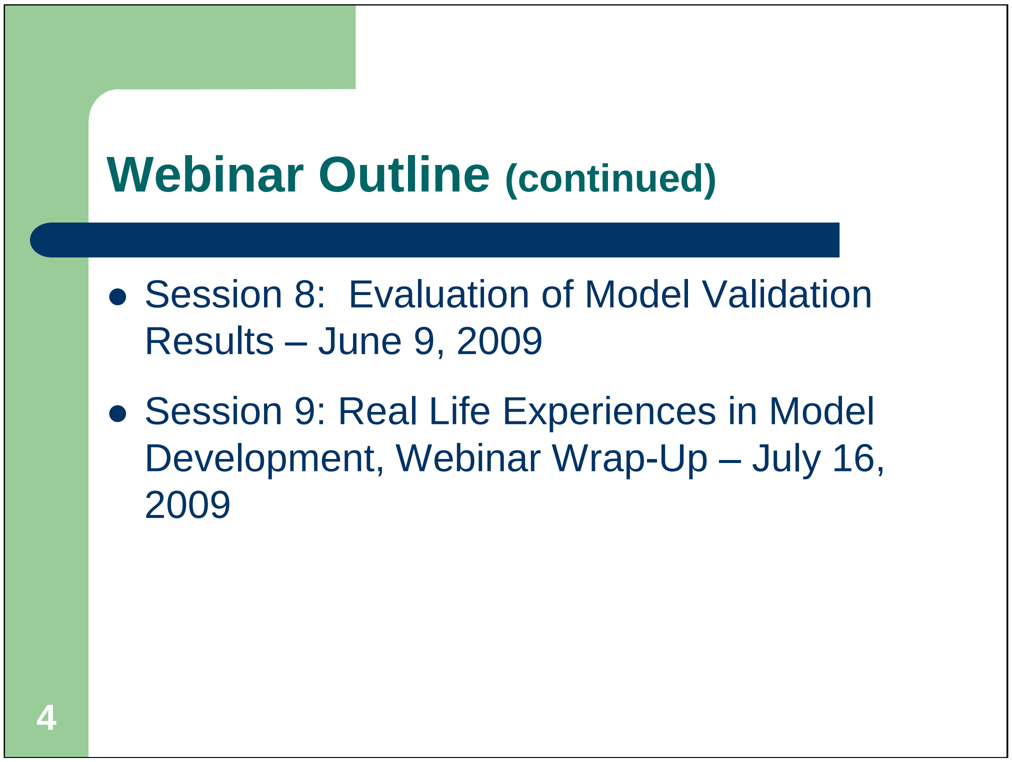
This is the webinar outline. These sessions have already occurred.




**Key Message: Upcoming Sessions**

**Details:**

After today's Session 7, Session 8 will be conducted on June 9, 2009.




**Key Message: Upcoming Sessions**

**Details:**

Session 8 will be conducted on June 9 and a new Session 9, on real life experiences in model development and the webinar wrap-up, will be held on July 16.

## Outline for Today

1. Highway Assignment
2. Introduction of Homework
3. Transit Assignment

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**Key Message: Today's Outline**

**Details:**

We will cover two key topics today: highway assignment and transit assignment. We will try to understand the similarities and differences between these two steps in the modeling process.

We will also discuss the homework for today.

# Trip Assignment

- Trip assignment is route choice
- Directly considers the choices made by other travelers
- Typically is an aggregate process
- Time periods defined for the model
  - e.g. AM peak, PM peak, midday, evening

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**Key Message: Trip Assignment**

**Details:**

Trip assignment can be thought of as the "choice" of a route by an individual. But, the choice of the route is dependent on level of service measures on that route, which are in turn dependent on the route choices made by other travelers. If a lot of the other travelers choose the same rate as a given traveler, then the route may get congested and may affect your choice of the route in the first place. Therefore, there is a clear feedback between the route choices of other customers and your own choice.

Modeling trip assignment as an individual decision is possible but is fairly involved. Therefore, trip assignment is typically an aggregate process. Time periods are defined for the model, the daily trip table is apportioned into say, AM, mid-day, PM, Night and so on. These time period trip tables are then assigned to the highway network with the appropriate levels of service.

## Highway Assignment

- Input:  Vehicle trip tables for each time period, perhaps by class
  - SOV
  - HOV
  - Truck
  - Toll road users?
- Input:  Highway network (by class)
- Outputs:  Link traffic volumes and speeds by time period (by class)

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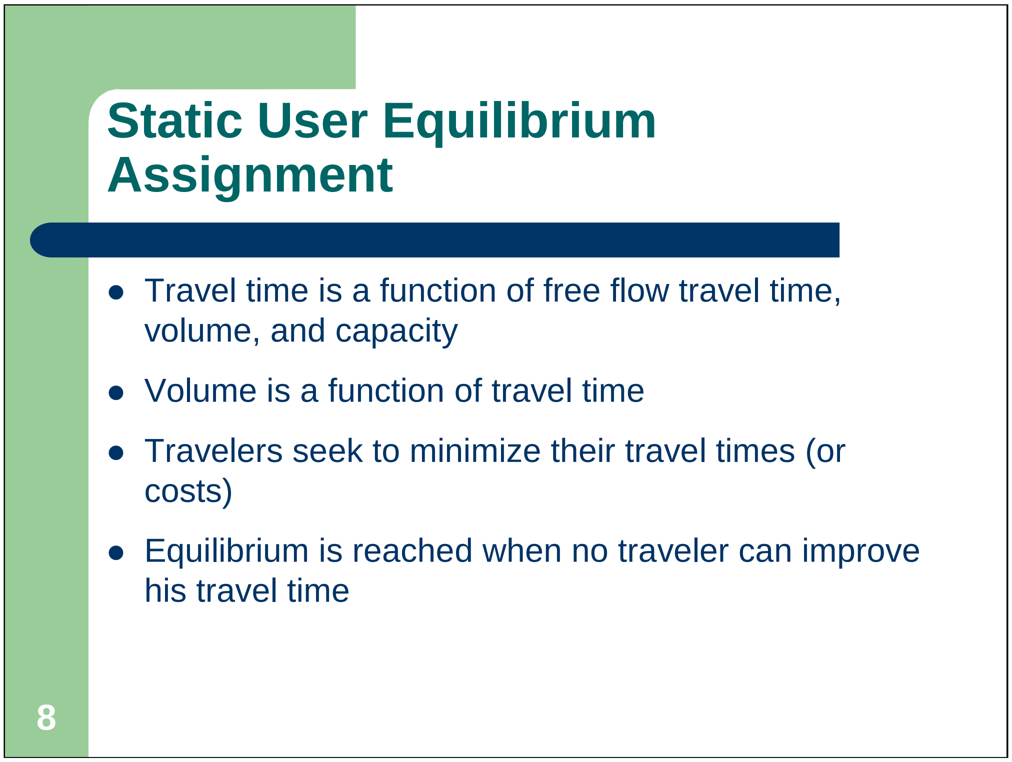
**Key Message: Highway Assignment**

**Details:**

There are two key inputs to the highway assignment process. First, we need vehicle trip tables for each time period by class. In other words, we will need vehicle trip tables for SOV, HOV, trucks, toll road users and so on. Second, we need the highway network to which we can assign these trip tables. In many locations, the highway network is different for SOV and HOV users because HOV users can use the HOV lanes, while the SOV users cannot. Similarly, toll road users will need to be assigned to the network with the toll links included, but the non-toll users will be assigned to a network that omits toll links.

The outputs of the highway assignment process are twofold: link traffic volumes on each link in the model highway network for each time period, and speeds on each link by each time period.




**Key Message: Static User Equilibrium Assignment**

**Details:**

Most assignments are static equilibrium assignments. So how does static user equilibrium assignment work?

There is an inherent circularity between traffic volume and travel time. Travel time on a link is a function of free-flow times, volume on that link and the capacity. But the volume on the link itself is a function of travel time! This circularity necessitates an iterative way of determining link volumes. We first start with the free-flow levels of service and obtain an initial set of volumes. Then, we re-calculate the new travel times with these volumes, and once again repeat the entire process.

In an equilibrium assignment we iterate until we reach an equilibrium. An equilibrium is reached when no traveler can improve her travel time by changing paths.

# Equilibrium Assignment
## Practical Considerations

- Implemented as a weighted average series of all-or-nothing assignments
- Each modeling software package has its own algorithms for computing equilibrium
  - Computing shortest paths
  - Computing weights
- Convergence measures
- Comparisons of scenario results

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**Key Message: Static User Equilibrium Assignment – Practical Issues**

**Details:**

The travel modeling software treats equilibrium assignment as a series of all-or-nothing assignments. That is, for a zone pair connected by multiple paths, the software assigns all the trips between the zone pair to the path that has the lowest travel time (or cost). The software now calculates the new travel times on each path based on these volumes. Using these new travel times, the software performs a second iteration of assignment and so on.

Convergence is achieved when all the paths between each zone pair have the exact same travel time (or cost). If this were not the case, then the travelers on one path can shift to another path with a lower travel time and improve their travel times; in such a case we would not have attained equilibrium.

Typically software assigns weights to each iteration's volumes. These weights are used mostly to achieve convergence in a quicker fashion. The computation of weights itself may vary from software to software. Please work on the homework to understand the dynamics of static user equilibrium assignment.

Another important consideration is to determine when we have achieved convergence? Defining the convergence measures to be very small and aggressive can increase the computation time quite substantially. However, it might be necessary to target tighter convergence measures to eliminate illogical results across scenarios.

## Highway Assignment
### User Settings

- Convergence/number of iterations
- Definition of impedance function
  - Time
  - Distance
  - Cost
  - What is not included
- Hourly/period conversion factor

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**Key Message: Common User Settings in Commercial Software**

**Details:**

In most software packages, we are able to define the convergence criterion or the number of iterations. We can also control what we use to compute impedance. For example, we could use a combination of time, cost and distance to define a composite impedance, or we could use each of these measures independently. Note that the reliability of travel times and the safety of paths are key determinants in determining impedance. However, these don't feature directly in the impedance function because they are hard to measure. This is a drawback of the current methodologies, although research is underway to incorporate these factors into the definition of impedance.

Another important user input is the conversion factors from hourly to period volumes. Most often capacity of links is coded in terms of vehicles per hour. However, as we noted, the assignment is often conducted on a period basis (AM, PM etc). To convert the capacities from hourly to period, we will need conversion factors. The magnitude of these factors depends on what percentage of a period's volume occurs during a peak hour.

## Volume-Delay Functions

$T_k = f(T_{0k}, v_k, c_k)$

"BPR formula"

$T_k = T_{0k} [ 1 + a (v_{k/}c_k)^b ]$

where:

$T_k$ = travel time on link k

$T_{0k}$ = free flow travel time on link k

$v_k$ = volume on link k

$c_k$ = capacity on link k

a, b model parameters

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**Key Message: Volume-Delay Functions**

**Details:**

A volume-delay function basically relates the travel time on a link to the free-flow time on that link, the traffic volume on that link and the capacity of the link.

The most common formulation is the BPR formula that you see here. The formulation has two parameters **a** and **b**. The values of a and b vary by functional class and so on. We will discuss more about this.

Note that the BPR formulation ensures that the travel time on a link NEVER falls below the free-flow travel time. Also, we note that as volume-capacity ratio increases, the travel time will start to increase rapidly.

## The BPR Formula

- Parameters a, b are not estimated
  - May be borrowed from another model
  - May be asserted
  - May be revised during calibration
- Higher a increases sensitivity of time for lower v/c
- Higher b increases sensitivity of time for higher v/c
- May vary among links (e.g. by facility type)

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**Key Message: The BPR Formula**

**Details:**

The parameters **a** and **b** are not typically estimated. These are either borrowed from other models or asserted. Naturally, these parameters can be fine-tuned during the calibration process.

The parameter **a** increases sensitivity of time for lower v/c links, while the parameter **b** increases sensitivity for high v/c links.

The parameters **a** and **b** vary by facility type. For example, interstates have different **a** and **b** values than for arterials.

## The BPR Formula

Examples of parameters:

| a | b |
|---|---|
| 0.07 | 6.0 |
| 0.10 | 4.0 |
| 0.15 | 4.0 |
| 0.15 | 8.0 |
| 0.68 | 5.5 |
| 0.71 | 2.1 |

| a | b |
|---|---|
| 0.83 | 2.7 |
| 0.83 | 7.0 |
| 0.88 | 9.8 |
| 1.00 | 5.4 |
| 1.16 | 6.0 |
| 1.50 | 5.0 |

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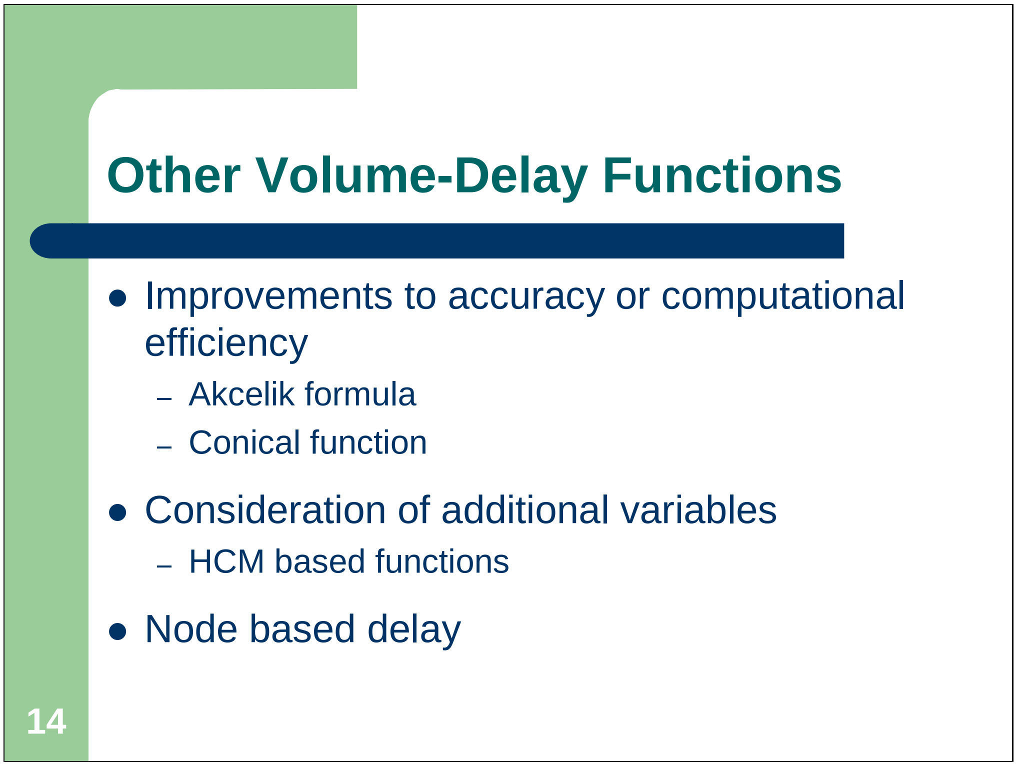
**Key Message: The BPR Formula**

**Details:**

Several values of **a** and **b** have been proposed in literature. This table shows some values actually used in U.S. urban area travel models. The right parameter for your region may be found by researching model areas that have similar traffic volumes as your area. Of course, you would also want to fine tune these parameters based on the calibration results.

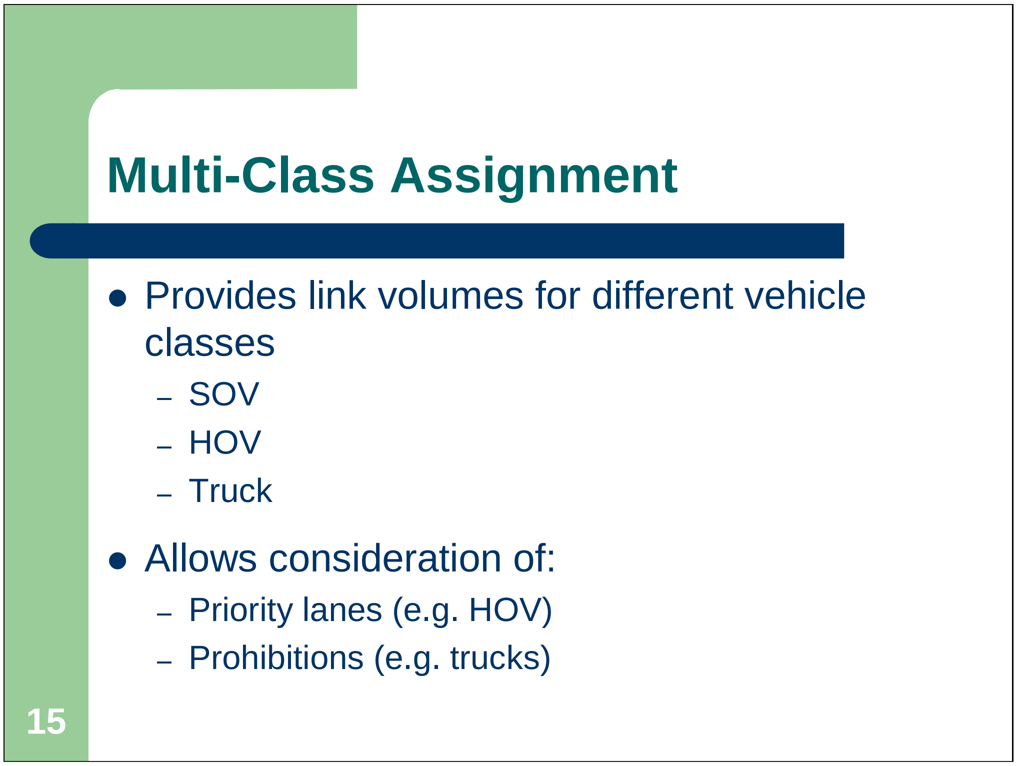



**Key Message: Other Volume Delay Functions**

**Details:**

The BPR formula is by no means the only volume-delay function. Several alternate forms are available in literature. These alternate formulations either try to improve the accuracy and computational efficiency of the process, such as with the Akcelik formula and the conical function, or consider additional variables, such as with the HCM-based functions.

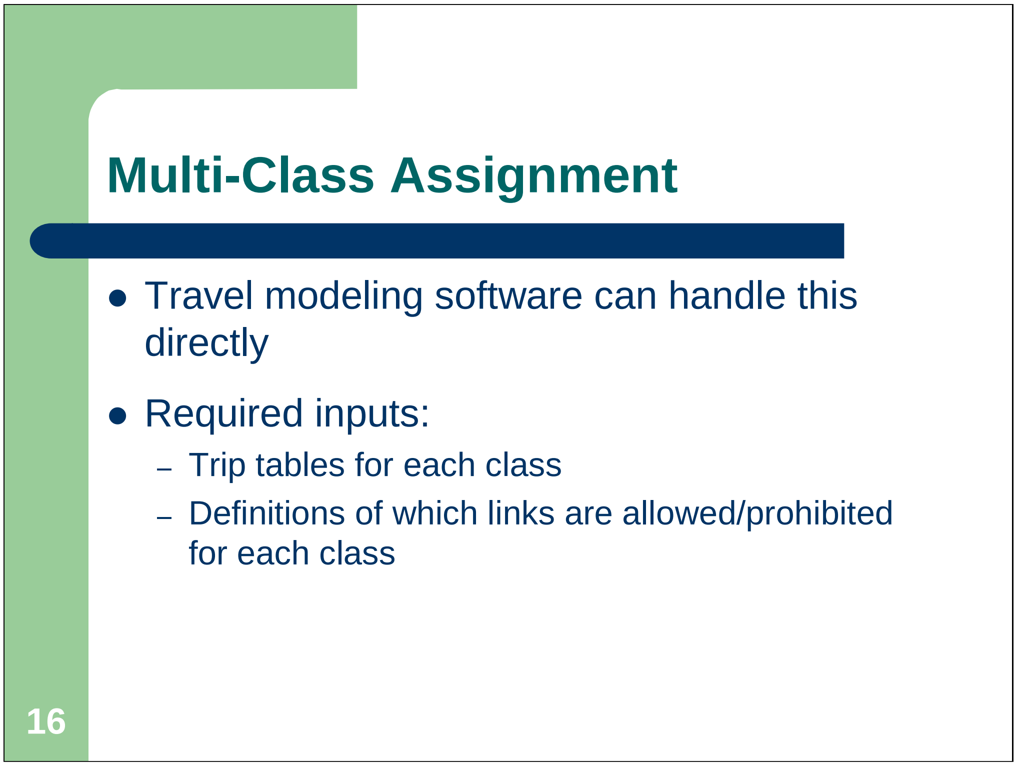
More advanced formulations also consider node-based delay as opposed to a link-based delay function.




**Key Message: Multi-Class Assignment**

**Details:**

Multi-class assignments provide separate volumes for SOVs, HOVs and trucks using separate assignments for these three classes of vehicles. As we already discussed, multi-class assignment allows for the consideration of priority lanes, such as for HOVs, and also for prohibitions, such as for no-truck routes.




**Key Message: Multi-Class Assignment**

**Details:**

All commercial travel modeling software can handle multi-class assignment directly. The software will need separate trip tables for each class and also indicators for which links are allowed or prohibited for each class of vehicles.

## Some Highway Assignment Questions

- Why are roads assigned above capacity?
  - Capacity is an abstract concept
  - “Saturation flows” have increased
  - The trips all have to be assigned

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**Key Message: Some Highway Assignment Questions**

**Details:**

How can volume to capacity ratio be above 1? This question puzzles many people. The reason for this is because capacity is an abstract concept in travel modeling. Capacity can change over time if driving behavior changes (that is, if people are willing to leave lesser space between cars) or if technology improves the speeds at which we people can drive, thereby allowing more cars to pass through a point.

When we assign trips to a network, we will have to make sure that trips are not “lost” in the process. To accommodate for this issue, and due to the fact that capacity itself is not concretely defined volume to capacity ratios over 1 are allowed in travel models.

So what V/C ratio is deemed unacceptable? There is no clear answer for this, but clearly we can’t allow a V/C of 5! This is surely unreasonable.

## Some Highway Assignment Questions

- Can peak spreading be handled directly by…
  - Static equilibrium assignment?
    - No
  - Traffic simulation?
    - No, only spillover to later periods
  - Post processors?
    - Only in a manual, rule based manner
  - Time of day choice models?
    - Yes, in theory
  - Activity based models?
    - Yes, but need data to calibrate

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**Key Message: Some Highway Assignment Questions**

**Details:**

We don’t say anything in a static equilibrium assignment about how the traffic is spread across the period. Traffic simulation cannot be used to do this either. One could use rule-based post-processors to address these issues in part.

Time-of-day models can certainly be used to apportion daily demand into finer time periods. These time period-specific tables can then be assigned to address peak spreading.

Activity-based models can be used to model peak-spreading. This has been done in practice, but requires data to calibrate the peak-spreading models.

## Some Highway Assignment Questions

- How can link volumes/times be affected by other links?
  - Intersections (including opposing left turns)
  - Merges/weaves
  - Queuing/spillover
- How can link interactions be handled?
  - Node based delay
  - Traffic simulation

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**Key Message: Some Highway Assignment Questions**

**Details:**

So far, we have treated link volumes and times as functions only of the volume or time on that link. However, when there are left turns, or merge/weave situations, or queuing/spillover issues, the times on a given link can be impacted by conditions on other links.

These interactions can be handled using traffic simulation or node-based delay techniques. A lot of research is underway on these topics.

## Homework

### Session 7

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**Key Message: Homework**

**Details:**

The homework for Session 7 can be downloaded from the course website. We would strongly recommend that the participants work through the homework problems to get more value out of this session.

# Transit Assignment
## Decisions for the Modeler

- Network decisions
  - Relationship between bus and highway speeds
  - Fare representation
  - Coding decisions
- User settings
- Single path vs. multipath

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**Key Message: Transit Assignment – Modeler Decisions**

**Details:**

Before the transit assignment step is conducted, the modeler will need to determine how the bus speeds will relate to the highway speeds. Usually, the bus speeds are not the same as the highway speeds. Typically, customized formulas are developed by the modeler to establish a relationship between bus and highway speeds based on roadway type, level of congestion, signal priority availability, whether the service is express or local etc.

Another decision item for the modeler is how the transit fares should be represented. Complex fare systems such as free-fare zones, graded fare-zones, peak/off-peak fares, transfer fares, monthly pass usage complicate the actual fare that a traveler perceives. Representing all of these in a single level of service matrix is often challenging.

How we code routes that do not have the same set of stops for different runs is also a decision item.

The modeler also needs to determine the user settings to use for assignment and also whether a single path or multipath assignment is used.

## Transit Assignment
### User Settings

- Relative weights of level of service variables
  - In-vehicle time
  - Walk/wait time
  - Transfer penalty
  - Consistency with mode choice model parameters
    - How do you get skims with which to estimate the mode choice model?
- Walk/auto access rules

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**Key Message: Transit Assignment – User Settings**

**Details:**

In determining the impedance of paths for transit assignment, the modeler often needs to specify the relative weights of out-of-vehicle times and other level of service variables vis-à-vis the in-vehicle time. These relative weights tell us, for example, how much more onerous out-of-vehicle time is corresponding to in-vehicle time. These weights should be consistent with mode choice model results. Of course, the obvious question here is if we want to use relative weights from mode choice, then how do we get the skims that are used to estimate mode choice models in the first place? Well, again we see circularity here, and the only way to break this is by starting with reasonable weights for the first round of skims, using these skims in the mode choice model, and then regenerating skims using the new weights implied by the mode choice model.

Another user setting is the accessibility of transit to walk and auto. Typically, modelers adopt distance- or time-based rules to identify zones that can access a bus stop or station by walk. For example, zones that are more than, say, 0.5 miles from a bus stop, will not be able to access the stop by walk. Also, the availability of park and ride zones determines the availability of auto access to a bus stop or station.

# Transit Assignment
## User Settings (continued)

- Other rules
  - Maximum number of transfers
  - Wait time limits
  - Transfer walk limits
  - Maximum trip time
  - Minimum in-vehicle trip times

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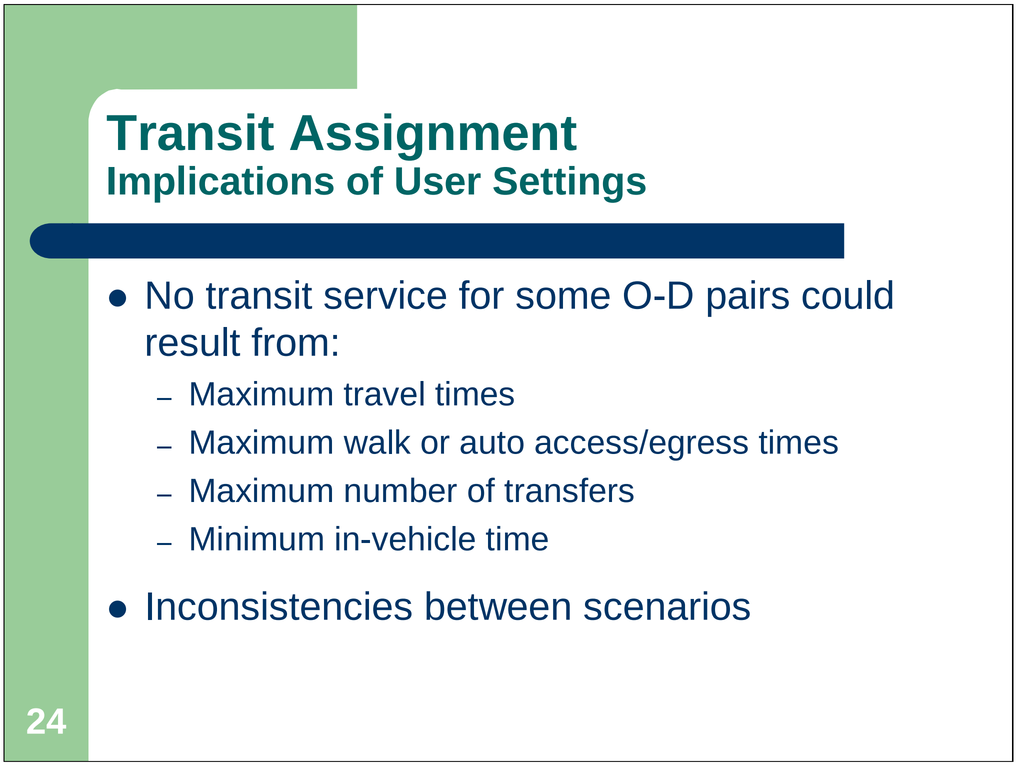
**Key Message: Transit Assignment – User Settings**

**Details:**

Several other rules can be specified prior to transit assignment. These include the maximum number of transfers allowed for a transit trip, the maximum wait time, the maximum walk times on a transfer link, the maximum total trip time and even the maximum in-vehicle time.

These rules are meant to filter out definitely infeasible transit paths, thereby reducing computation time and minimizing spurious results.




**Key Message: Transit Assignment – Implications of User Settings**

**Details:**

Of course, the user settings will have implications for the model results. As an example let’s say we have a maximum walk distance to transit of 1 mile. Let’s say in the base scenario we have a bus stop 0.95 miles from a zone. Now, let’s say the build scenario replaces this bus stop with a train station, but the train station is 1.05 miles away from the same zone. Now, the zone can no longer access the train station by walk.

One needs to be mindful of such results while defining the rules and while comparing scenarios.

## Single Path vs. Multipath Transit Assignment

- Definition of path:

  The sequence of links and nodes, including walk/auto access and egress portions of trip, used to travel from the origin centroid to the destination centroid

- This defines the routes taken, in order, and the boarding, alighting, and transfer stops.

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**Key Message: Single vs. Multipath Transit Assignment**

**Details:**

A path is defined as a sequence of links and nodes, including the walk access or auto access and egress portions of trip, used to travel from the origin zone centroid to the destination zone centroid.

In a transit context, a path defines the routes taken, in order, and also the boarding, alighting and transfer stops.

# Single Path vs. Multipath Transit Assignment (continued)

- Single path advantages
  - Simpler
  - Accurate for simple transit networks
- Multipath advantages
  - Only way to get accurate route boardings in less simple networks
  - Supported by most modeling software

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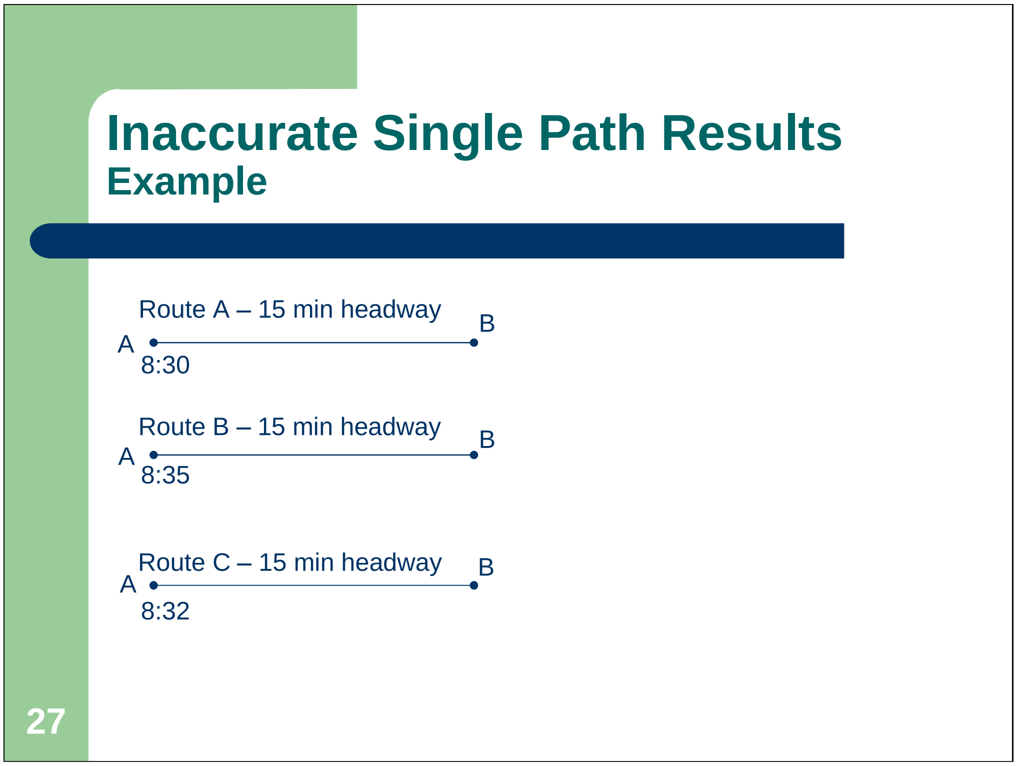
**Key Message: Single vs. Multipath Transit Assignment**

**Details:**

Single path is akin to an all-or-nothing assignment. All transit trips are assigned to a single transit path. Multipath allows for the assignment of transit trips to multiple transit paths between a zone pair.

Single path is OK when the transit system is simple. But for more complicated systems multipath is advisable, and even necessary to get boardings on all transit routes. All commercial travel modeling softwares support multipath assignment.



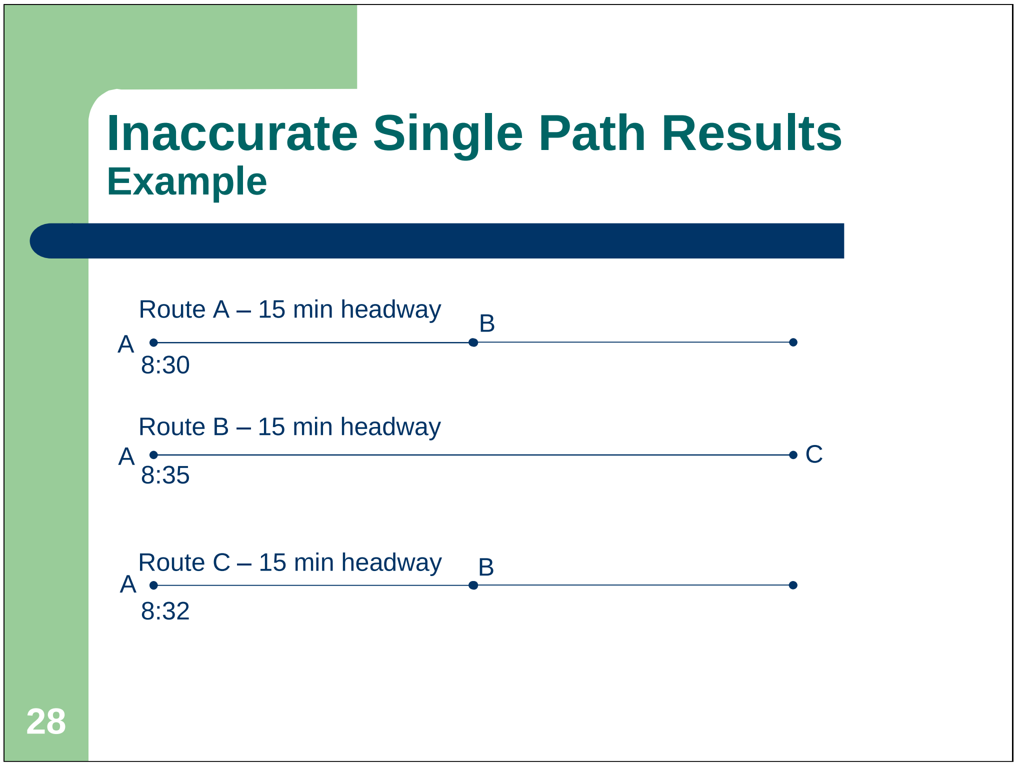

**Key Message: Some examples of Inaccurate Single Path Results**

**Details:**

Say there are three transit paths between zones A and B, with exactly the same level of service characteristics, a single path assignment could pick any one of these routes to assign the entire volume.

However, the multipath assignment would deem each of these paths as equally likely and would assign a third of the trips to each of the three routes.

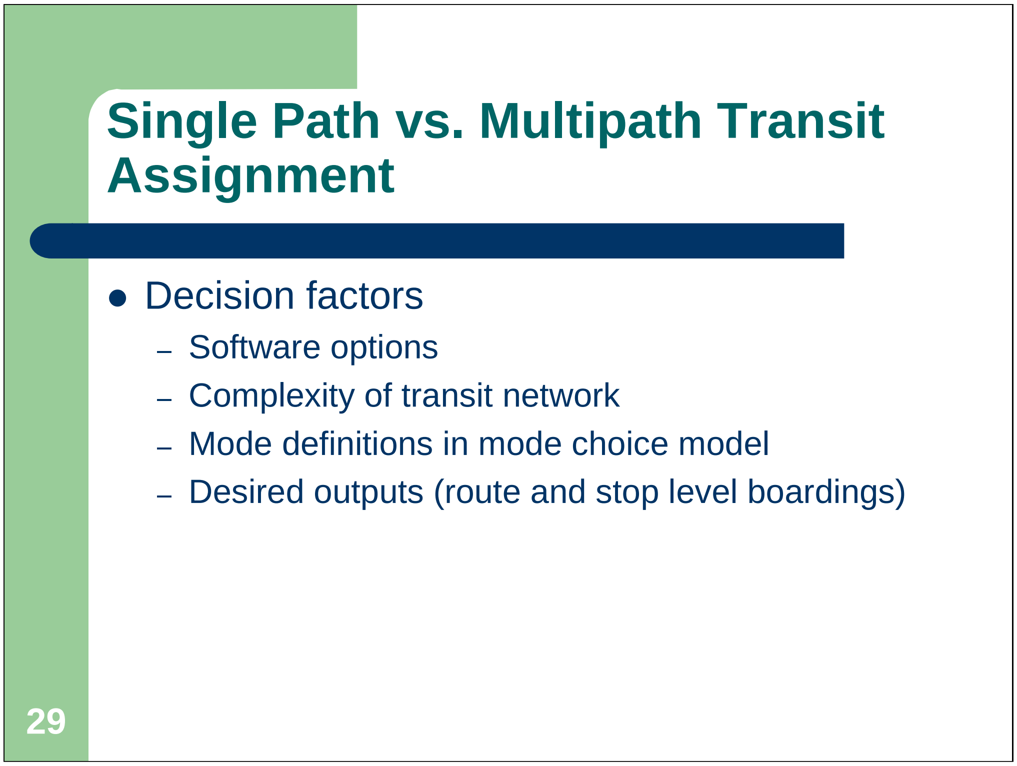
Now, if we have schedule information as well. Route A departs at 8:30, route B at 8:35 and route C at 8:32, we would end up with 2/3 trips are assigned to route A.




**Key Message: Some examples of Inaccurate Single Path Results**

**Details:**

If in addition we know that Route B does not stop at B, then route B will not even be an option and route A will be an even more likely route.




**Key Message: Single vs. Multipath Assignment**

**Details:**

The decision between single and multipath assignment depends on the software options and the complexity of the transit system.

The definitions of modes in the mode choice model also determine the choice of single vs. multi path assignment. If the mode choice model only defines walk and drive access to transit as the options, then it would be incorrect to do a single path assignment because the transit trip table is rather generic and the trips will need to be loaded on to any of a number of options. If on the other hand, the mode choice model uses more disaggregate modes such as commuter rail, light rail etc., then a single path assignment may be justifiable.

Another factor that determines the choice of single and multi path assignment is the level of desired outputs. If route and stop-level boardings are necessary, then, single path assignment is not advisable.

## Schedule Based Transit Assignment

- Current procedures are headway based
  - Trips not assigned to particular transit runs
- Schedule based assignment
  - Assigns trips to particular runs/vehicles
  - More accurate representations of wait times/transfer times, etc.
  - Requires mode detailed time of day travel information
  - Well suited for implementations with activity based models

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**Key Message: Schedule Based Transit Assignment**

**Details:**

Current procedures are based on headways. That is, trips are assigned to a route and not to a specific run of a route. In our example, we saw that trips are assigned to routes A, B or C, but not to the 8:30 run of route A or the 8:45 run of route A.

Schedule based assignment circumvents this problem by assigning to each run. This can give us a lot more accurate representation of wait times, but it does require more detailed information on time-of-day of travel. Therefore, this methodology is more suited for activity-based model approaches where such information is readily available.